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Measuring adolescent science motivation

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ABSTRACT
To monitor science motivation, 232 tenth graders of the college preparatory level ('Gymnasium') completed the Science Motivation Questionnaire II (SMQ-II). Additionally, personality data were collected using a 10-item version of the Big Five Inventory. A subsequent exploratory factor analysis based on the eigenvalue-greater-than-one criterion, extracted a loading pattern, which in principle, followed the SMQ-II frame. Two items were dropped due to inappropriate loadings. The remaining SMQ-II seems to provide a consistent scale matching the findings in literature. Nevertheless, also possible shortcomings of the scale are discussed. Data showed a higher perceived self-determination in girls which seems compensated by their lower self-efficacy beliefs leading to equality of females and males in overall science motivation scores. Additionally, the Big Five personality traits and science motivation components show little relationship.

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Science motivation; assessment; personality traits; self-efficacy; secondary education; Big Five

Introduction

Many studies analysing attitudes, interest and motivation of students towards science point to a decreasing tendency during school careers, especially in secondary school (e.g. Osborne, Simon, & Collins, 2003). Lack of motivation in science may interfere with the scientific literacy needed for responsible decision-making and behaviour, and cause a decrease in the motivation to choose a career related to science; girls in particular are affected by this (Rocard et al., 2007). One approach to counteracting this may lie in better methods of assessing motivation in science to understand students' needs for tailored teaching programmes and methods. To support learners in a targeted way, we need to characterize (un)motivated students as precisely as possible, as well as to analyse certain aspects of motivation.

Motivation towards learning science

Motivation to learn science is often defined as 'an internal state that arouses, directs, and sustains science-learning behaviour' (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011, p. 2). Motivation plays a big role in learning science, promoting academic success and provoking more help-seeking behaviours and commitment (Schunk, Pintrich, & Meece, 2008). For teachers (or lecturers), it is important to understand students' lack of

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motivation, and how to counteract, for example, by providing assistance in self-assessment and goal setting (Pajares, 2002), or by increasing autonomy (Black & Deci, 2000). This implies the need for valid tools to assess motivation. Measurement of science motivation can also help in examining relations between motivational components and other factors like personality (see this present study), academic performance or intelligence.

The search for appropriate tools to measure science motivation is not new (for an overview, see Lovelace & Brickman, 2013). The most up-to-date questionnaire with high quality and simple language seems to be the Science Motivation Questionnaire (SMQ/SMQ-II, Glynn, Taasoobshirazi, & Brickman, 2009; Glynn et al., 2011), primarily developed for college courses to identify unmotivated students in order to address their special requirements (Glynn & Koballa, 2006). A multicomponent construct provided the frame for assessing science motivation (of college students), combining important motivational factors: intrinsic motivation in combination with personal relevance, extrinsic motivation differentiated in grade and career motivation as well as self-determination and self-efficacy (Glynn et al., 2009). The model itself was grounded on the social-cognitive theory of human learning (Bandura, 1986). Of the many motivational components linked to learning science (see Glynn & Koballa, 2006; Glynn et al., 2009; Schunk et al., 2008), Glynn et al., (2011) extracted five factors, already mentioned above, as essential:

Intrinsic motivation is the drive we feel when we do something because it is inherently interesting or enjoyable (Ryan & Deci, 2000). A reward for performing an intrinsically motivated activity is the activity itself. Consequently, intrinsic motivation is regarded as an important factor influencing academic achievements; items in the SMQ-II refer to curiosity, interest, value and pleasure on science/science learning.

When extrinsically motivated, we do something because it leads to a tangible outcome (Ryan & Deci, 2000). In a scholastic setting, concrete outcomes are grades, as short-term goals, and potential professions as long-term results of achievements during the school career. In these two extrinsic motivators, two opposite ends of a continuum were identified: the motive of doing something because we expect external compensation (e.g. good grade as reward) or because we endorse the value or utility of the extrinsic goal (e.g. better career options) (Ryan & Deci, 2000).

Two further aspects are essential for understanding (intrinsic) motivation: the autonomy we feel in our acting and our perceived competence performing a task – self-determination and self-efficacy (Ryan & Deci, 2000). The self-determination theory takes into account the recurring finding that extrinsic rewards may weaken intrinsic motivation (Deci, Koestner, & Ryan, 1999; Deci & Ryan, 1985). In an educational context, this self-determination refers to the control a student perceives he has over his learning. The feeling of autonomy leads to positive impact on academic performance (Black & Deci, 2000) and is therefore interesting for research on science motivation with students. The SMQ-II items for assessing self-determination refer mostly to the effort and commitment students show in science classes ('I study hard … , I prepare well … , I put enough effort … , I spend a lot of time') and are, in contrast to the items of the other subscales, connected to behaviour patterns associated with achievement behaviour.

Self-efficacy is the individual's perception of competence to accomplish separable tasks and attain certain results (Pajares, 1996). According to social-cognitive theory, we are more motivated to learn if we believe we can achieve the desired result (Bandura, 1986), whereas if we have low self-efficacy, we are afraid of difficult tasks because we have negative expectations and do not believe in our ability to manage the task (Glynn et al., 2009). Therefore, it is not surprising that, for example, Pajares (2002) postulates self-efficacy as a very strong predictor of academic achievement. Furthermore, self-efficacy beliefs are also held responsible for influencing adolescents' career decisions (Bandura, Barbaranelli, Caprara, & Pastorelli, 2001).

Early studies applied the SMQ of 2009 with no adaptation in wording to younger age groups (e.g. Bryan, Glynn, & Kittleson, 2011 or Zeyer et al., 2013) and confirmed the SMQ or parts of it as applicable to secondary school students.

As noted earlier, understanding of motivational aspects may lead to overcoming motivational barriers to learn science, since one aspect of Glynn's et al., (2011, p. 14) scale is to 'examine relationships between student's motivation and students' characteristics'. According to Rothstein, Paunonen, Rush, and King (1994), science motivation components and personality traits are considered to influence scholastic success, whereas science achievement is regarded as dependent on science motivation (e.g. Singh, Granville, & Dika, 2002). Since personality traits reveal what a person will do (e.g. Furnham & Chamorro-Premuzic, 2004), they should be especially related to action-oriented items of the SMQ-II.

The Big Five

Tupes and Christal (1961) first hypothesized a five-factor structure of personality by analysing adjectives describing human characteristics. In the 1980's, McCrae and Costa (1985, 1987) finally confirmed the five main factors as valid: Extraversion, Agreeableness, Conscientiousness, Neuroticism and Openness. Later on, Goldberg (1990) labelled this set the 'Big Five'. McCrae and Costa (1987) showed the validity of the five-factor personality model across instruments (adjective factors and questionnaire) and observers (self-reports and peer ratings). A later study of McCrae and Costa (1997) suggested that the Big Five personality trait structure is applicable in different cultural backgrounds. Soto, John, Gosling, and Potter (2008) confirmed the five-factor structure with about 230,000 subjects aged 10–20 with the original Big Five Inventory (BFI; Benet-Martínez & John, 1998; John, Donahue, & Kentle, 1991; John & Srivastava, 1999) for all ages. Soto et al., (2008) reported for adolescents above 14 years fewer differences in their personality self-reports compared to younger ones, which implies the applicability of personality self-reports to secondary school students. O'Connor and Paunonen (2007) showed the Big Five factors to be strongly predictive of scholastic success. We assume the Big Five to be an appropriate model to analyse relations to science motivation in a scholastic setting. A short questionnaire to assess the Big Five personality traits is the BFI-10 (Rammstedt & John, 2007) with 10 items.

To allow a more detailed description of motivational facets of learners, we collected data of the science motivation of upper secondary school students, tested if the instrument (SMQ-II) is applicable for our target group, examined differences in motivational components and examined potential relationships between science motivation and personality. Our research questions were the following:

- Is the SMQ-II a valid instrument for measuring the science motivation of upper secondary school students?

- Can we confirm the structure of science motivational components for upper secondary school students?
- Are there gender differences between the components of science motivation?
- Are personality traits correlated with science motivation components of upper secondary school students?

Methods

232 Bavarian 10th graders of the college preparatory secondary school level ('Gymnasium') ($M \pm$ SD: 16.02 ± 0.56; 50.41% females) participated in our study. The questionnaires were completed one week before participation in one of our regular learning programmes. Teachers registered their classes for the learning programme and students gave their informed consent to participation.

We applied the SMQ-II (Glynn et al., 2011) with 25 items (each subscale has five items) for monitoring: intrinsic motivation, career motivation, self-determination, self-efficacy and grade motivation. The response pattern followed a 5-point Likert scale from never (1), rarely (2), sometimes (3), often (4) to always (5). We used the German version of the SMQ-II slightly adapted to the German school system (e.g. conversion of US grade system as used in the original scale, for example, 'A' as best grade in the German grade system '1' as best grade).

We also assessed the Big Five personality traits: extraversion, agreeableness, conscientiousness, neuroticism and openness using the 10 items version of the Big Five Inventory BFI-10 (Rammstedt & John, 2007). The questionnaire was designed for research settings with time restrictions and has been published in a German version. It was tested by Rammstedt and John (2007) for retest reliability, structural validity and convergent validity with the NEO-PI-R questionnaire with 48 items (Costa & McCrae, 1992) and part–whole correlation with the BFI-44 questionnaire with 44 items (Benet-Martínez & John, 1998; John & Srivastava, 1999; John et al., 1991). Rammstedt and John (2007) confirm that the BFI-10 offers a sufficient level of reliability and validity and can therefore be used in contexts where time is limited. The response pattern again followed a 5-step Likert scale from disagree strongly (1) to agree strongly (5).

For our statistical analysis, we used SPSS (Version 22.0). First, we applied an exploratory factor analysis to the SMQ-II to test if our results correspond with those of Glynn et al., (2011). We used oblique rotation because relations between motivational components are likely (e.g. Ryan & Deci, 2000). For analysis of the adequacy of our sample, the Kaiser–Meyer–Olkin (KMO) test (Kaiser, 1970) and Bartlett's test of sphericity were examined. The correlation matrix was checked for very high ($r > 0.9$) and very small correlations ($r < 0.3$). After the first analysis, items 22 and 25 were removed due to loadings deviating from the hypothesized structure (Glynn et al., 2011) and high cross loadings (over 0.3). Subsequently, factor analysis was applied again. In the anti-image matrix, we targeted diagonal elements <0.5 and off-diagonal elements with high values. We also performed the KMO test again and calculated Cronbach's α for the remaining 23-item scale and for each subscale. Again, the item correlation matrix and correlations between motivational components were examined.

Kaiser–Guttman criterion (eigenvalue of factor greater than one, Kaiser, 1960) was employed to determine the number of factors to extract. The number of variables in

International Journal of Science Education 2016.38:434-449.

our analysis as well as the communalities (see below) suggests that this criterion should produce an accurate solution (see Stevens, 2009).

Following the central limit theorem, we assumed normal distribution of the data and examined differences between subscale of the SMQ-II and gender differences within the subscales for the first with paired sample *t*-test and with independent sample *t* -test for the latter. The effect size measures (Cohen's *d*) followed Glynn et al., (2011). Because only complete sample sets have been included in our analysis, the sample size differed slightly in the different measures (see Table 1). For each correlation between subscales of SMQ-II and those of BFI-10 (Rammstedt & John, 2007), we calculated a two-tailed level of significance and the corresponding 95% confidence interval (CI). The Bonferroni correction was applied (level of significance $p < .002$). For our statistical analysis, we used SPSS (Version 22.0).

Results

Factor analysis

As postulated by Glynn et al., (2011), using an exploratory principal axes factor analysis with oblique rotation, we extracted a five-factor structure from the SMQ-II on the basis of eigenvalues >1.0 (Kaiser, 1960) explaining 69.55% of the total variance. Also, the scree-plot showed inflections that justify assuming five factors. All factor loadings show values above 0.3 on their main factor; the KMO value of 0.91 indicates distinct and reliable factors (Kaiser, 1970). Diagonal elements of the anti-image Matrix are all above 0.79. Most of the off-diagonal elements were small (less than or equal to 0.42). The Barlett test was significant ($p < .001$) indicating that correlations between items are significantly different from zero (Field, 2013). Seven per cent of the residuals rated higher than 0.05, indicating that the observed correlation coefficients and correlation coefficients predicted by the model are very similar. The pattern matrix of the first-factor analysis after rotation with the 25-item set is shown in Table 2. Cronbach's α of 0.91 indicates a good overall reliability according to Kline (1999). The loading pattern followed the one observed by Glynn et al., (2011), with the exception of items 22 and 25 (due to following the postulated structure). We decided to exclude these items from further calculations.

A repeated factor analysis produced a clear structure of five factors based on Kaiser–Guttman criterion (Kaiser, 1960) as shown in Table 3. Most of the items loaded above 0.50. Significance of factor loadings depends on sample size and number of variables. With a small sample size relative to the number of variables, high factor loadings are required. For a sample size of $N = 200$, Stevens (2009) recommended a minimum loading of about 0.36 (for $N = 250$ a limit above 0.33 is needed). Our sample ($N = 226$) has met this criterion. Furthermore, even the lowest loading in Table 3 explains at least 19% of the variance (most of the loadings share far more variance with the construct),

Table 1. Descriptive statistics of analysed samples

		Age		Gender (%)	
	N	*M*	SD	Female	Male
Sample with complete SMQ-II	226	16.00	.568	48.7	51.3
Sample with complete SMQ-II and BFI-10	204	15.99	.546	49.5	50.5

Table 2. Exploratory factor analysis with SMQ-II after rotation ($N = 226$), df = 300. Table shows factor loadings >±0.3, $\alpha = 0.91$.

	Factor				
	1	2	3	4	5
SMQ 2	**0.76**				
SMQ 4	**0.67**				
SMQ 3	**0.63**				
SMQ 1	**0.62**				
SMQ 5	**0.62**				
SMQ 14		**0.87**			
SMQ 12		**0.85**			
SMQ 11		**0.76**			
SMQ 13		**0.75**			
SMQ 15		**0.45**			
SMQ 7			**096**		
SMQ 8			**0.90**		
SMQ 6			**0.89**		
SMQ 9			**0.74**		
SMQ 10			**0.69**		
SMQ 24				**−0.74**	
SMQ 23				**−0.54**	
SMQ 21				**−0.53**	−0.33
SMQ 17					**−0.83**
SMQ 16					**−0.81**
SMQ 18					**−0.70**
SMQ 19					**−0.64**
SMQ 22				−0.34	**−0.57**
SMQ 25				−0.33	**−0.50**
SMQ 20					**−0.46**
α	0.86	0.85	0.93	0.74	0.89

Note: Bold values are factor loadings.

clearly above the minimum threshold of 15% (Stevens, 2009). About 75% of the communalities after extraction lay in the 0.60 range or above and a further 20% in the 0.50 range. These values are of help in deciding whether Kaiser–Guttman criterion yields an acceptable number of factors. The KMO measure presented our sample as adequate for the analysis, KMO = 0.91 (acceptable limit 0.5, Field, 2013). Diagonal elements of the anti-image matrix were all above 0.80. Most of the off-diagonal elements were very small. The Barlett test was significant ($p < .001$). Five per cent of the residuals were greater than 0.05. Cronbach's α for the scale with 23 items was 0.91. A 70.93% of the total variance was explained by the factors. The remaining potential 18 factors account together for 29% of the variance. Stevens (2009) suggests a minimum of 70% of variance as a criterion for factor extraction, whereas, for example , Merenda (1997) proposes a minimum of 50%.

Detailed examination of the correlation matrix as described in Ferketich (1991) suggests correlation scores between .70 and .30 as desirable: the subscale self-determination (SDe) deviates from the rest of the items in providing sufficient inter-correlation scores within the subscale but not with the rest of the SMQ-II. Another outlier was item 23 with its average correlation below 0.3. The motivational components correlated significantly ($p < .001$), although the SDe subscale failed to correlate with intrinsic motivation (IM), career motivation (CM) or self-efficacy (SE). Similar to the results of Glynn et al., (2011), the highest correlation is between IM and CM.

Table 3. Exploratory factor analysis with SMQ-II after rotation (items 22 and 25 excluded, see text) (N = 226), df = 253. Table shows factor loadings >±0.3, α = 0.91.

	Factor				
	F1: IM	F2: SDe	F3: CM	F4: GM	F5: SE
SMQ 4 Learning science makes my life more meaningful	**0.71**				
SMQ 2 I am curious about discoveries in science	**0.69**				
SMQ 3 The science I learn is relevant to my life	**0.68**				
SMQ 1 Learning science is interesting	**0.56**				
SMQ 5 I enjoy learning science	**0.55**				−0.32
SMQ 14 I spend a lot of time learning science		**0.88**			
SMQ 12 I prepare well for science tests and labs		**0.84**			
SMQ 11 I study hard to learn science		**0.77**			
SMQ 13 I put enough effort into learning science		**0.74**			
SMQ 15I use strategies to learn science well		**0.44**			
SMQ 7 Understanding science will benefit me in my career			**0.95**		
SMQ 8 Knowing science will give me a career advantage			**0.90**		
SMQ 6 Learning science will help me get a good job			**0.89**		
SMQ 9 I will use science problem-solving skills in my career			**0.73**		
SMQ 10 My career will involve science			**0.69**		
SMQ 24 Getting a good science grade is important to me				**−0.88**	
SMQ 21 Scoring high on science tests and labs matters to me				**−0.57**	−0.33
SMQ 23 I think about the grade I will get in science				**−0.51**	
SMQ 17 I am confident I will do well on science tests					**−0.86**
SMQ 16 I believe I can earn a grade of 'A' in science					**−0.76**
SMQ 18 I believe I can master science knowledge and skills					**−0.75**
SMQ 19 I am sure I can understand science					**−0.69**
SMQ 20 I am confident I will do well on science labs and projects					**−0.48**
α	0.86	0.85	0.93	0.74	0.88

Notes: Bold values are factor loadings. IM, intrinsic motivation; SDe, self-determination; CM, career motivation; GM, grade motivation; SE, self-efficacy.

To conclude: our analyses yielded a five-factor solution of the SMQ-II. Nevertheless, the correlation matrix pointed to potential shortcomings of the instrument.

Analysis of scale scores

Our sample produced different mean values of the five subscales of the SMQ-II (Figure 1). The mean score of the whole SMQ-II was $M \pm SD = 3.07 \pm .75$ (broken line). With two-tailed t-test, significant differences between the subscales were found (Bonferroni correction not significant $p > .005$) between IM-SDe md = 0.29, CI (95%) [.15; .43], $t(225) = 4.18$, $p < .001$, IM- grade motivation (GM) md = −0.44, CI (95%) [−.55; −.32], $t(225) = -7.31$, $p < .001$, IM-SE md = −0.16, CI (95%) [−.25; −.06], $t(225) = -3.30$, $p = .001$, SDe-SE md = −0.45, CI (95%) [−.60; −.30], $t(225) = -5.83$, $p < .001$, SDe-GM md = −0.73, CI (95%) [−.85; −.60], $t(225) = -11.51$, $p < .001$, CM-SE md = −0.29, CI (95%) [−.42; −.16], $t(225) = -4.33$, $p < .001$, CM-GM md = −0.57, CI (95%) [−.70; −.43], $t(225) = -8.25$, $p < .001$ and GM-SE md = 0.28, CI (95%) [.15; .40], $t(225) = 4.41$, $p < .001$.

Students scored highest for GM followed by SE and IM (Figure 1). Mean scores of the subscales CM and SDe were lying under the overall means core of the SMQ-II. Note that two items (Nos 22 and 25, see above) from the original subscale GM were dropped.

Gender differences were analysed for the whole scale and each subscale. Neither IM nor CM nor the overall SMQ-II scale produced such a difference. Nevertheless, gender differences exist in the subscale SDe and SE (Figure 2). The independent samples t-test indicated

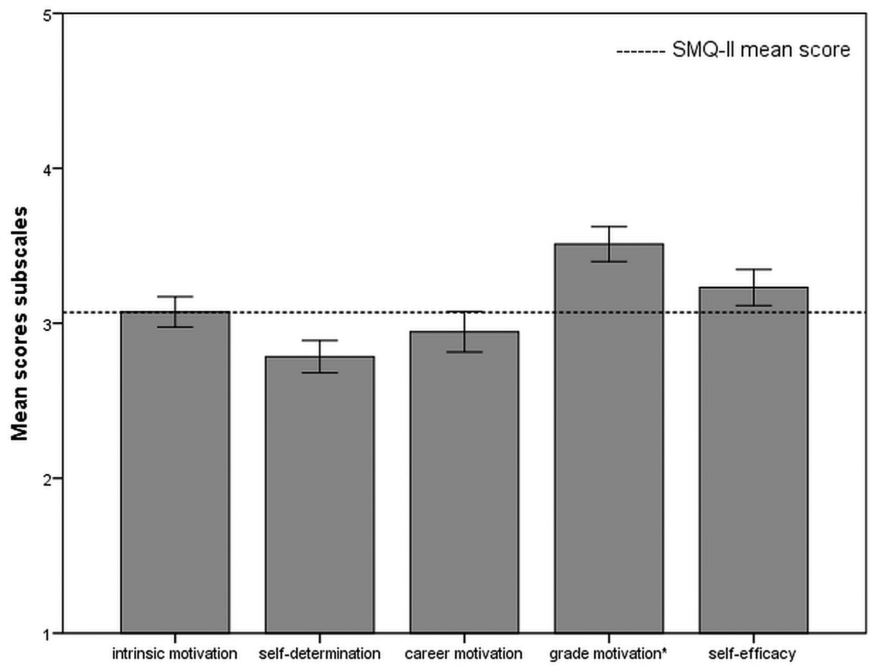

Figure 1. Comparison of the motivation components ($N = 226$). Error bars show 95% CI. *Mean score of three items (21, 23, 24) without items 22 and 25 (see text). Mean score for the whole SMQ-II $M \pm SD = 3.07 \pm .75$.

lower scores for males ($M \pm SD = 2.61 \pm .81$) in SDe compared to females ($M \pm SD = 2.98 \pm .75$). The difference −.37, CI (95%) [−.57; −.17]), was highly significant ($t(231) = -3.61$, $p < .001$) with an effect size of Cohen's $d = .47$. Similarly, a significant gender difference produced the subscale SE: females ($M \pm SD = 3.12 \pm .86$) vs. males ($M \pm SD = 3.37 \pm .91$) shows the difference .25, CI (95%) [.02; .48], $t(231) = -2.18$, $p = .031$, Cohen's $d = .28$.

We correlated the five subscales of the validated SMQ-II scale with the Big Five personality traits obtained from the short questionnaire BFI-10 (Rammstedt & John, 2007). Small correlations were found between SDe and conscientiousness ($p = .001$) and neuroticism ($p < .001$, see Table 4). No correlations for the Big Five personality traits and IM, CM, GM or SE were observed; neither were significant correlations between extraversion, agreeableness and openness and the domains of science motivation evident (all p's = n.s., see Table 4).

Table 4. Two-tailed Pearson correlation between SMQ-II subscales and Big Five subscales.

	Motivational facet				
Personality trait	Intrinsic motivation	Self-determination	Career motivation	Grade motivation	Self-efficacy
Extraversion	n.s.	n.s.	n.s.	n.s.	n.s.
Conscientiousness	n.s.	.237* [.094, .375]	n.s.	n.s.	n.s.
Neuroticism	n.s.	.269* [.123, .407]	n.s.	n.s.	n.s.
Openness	n.s.	n.s.	n.s.	n.s.	n.s.
Agreeableness	n.s.	n.s.	n.s.	n.s	n.s

$N = 204$. After Bonferroni correction $p > .002$ = n.s. (not significant), $^{*}p \leq .002$. BCa bootstrap 95% CI in squared brackets.

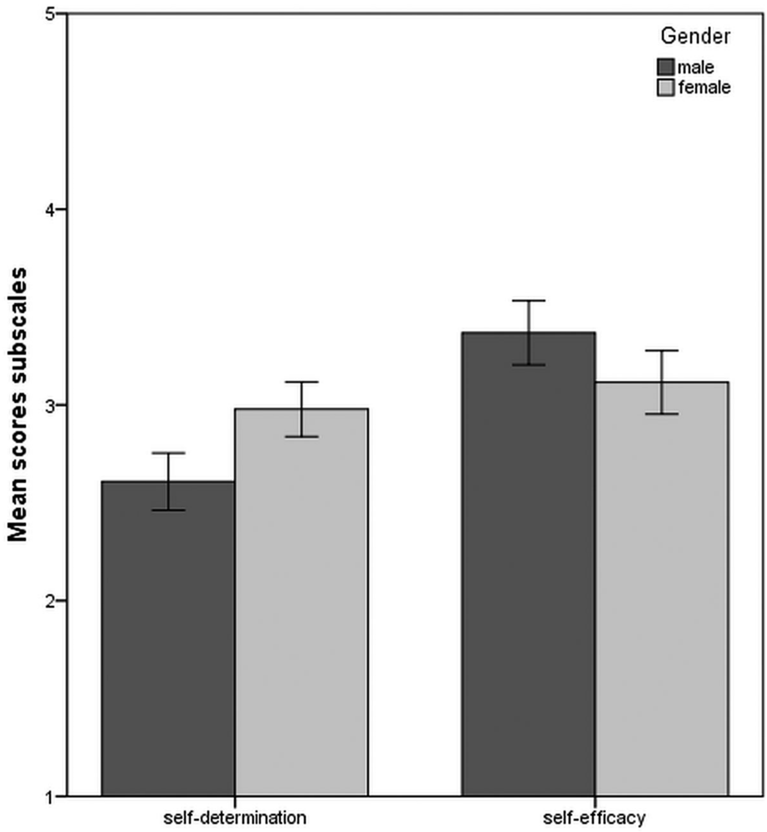

Figure 2. Gender differences in the two subscales of the SMQ-II: girls ($n = 110$) score higher in SDe and boys ($n = 116$) in SE. Error bars show 95% CI.

Discussion

Validation of the SMQ-II

After exclusion of two items with insufficient model fit, the scale apparently provides a valid and reliable tool to assess motivation in science. Nevertheless, some issues need discussion: first, the Kaiser–Guttman criterion (eigenvalue of factor greater than one, Kaiser, 1960) suggested five factors. Stevens (2009) regards this criterion as accurate when the number of items does not exceed 30, when the sample size is bigger than 250 and communalities are greater or equal to .60. As the sample size of this present study is slightly smaller, other criteria suggest the application of the Kaiser criterion leading to a reasonably precise result.

Second, the subscale self-determination correlates neither with most of the scale's motivational components, nor with most of the items of the other scales. Furthermore, two items of the subscale grade motivation loaded differently from that stated by Glynn et al., (2011). Glynn et al., (2011) or Goldschmidt and Bogner (2015) used Barlett's test and KMO value to prove validity of the SMQ-II (or parts of it) without noting detailed information about the correlation matrixes. Therefore, we do not know if the divergent conduct of the subscales grade motivation and self-determination is sample dependent or is related to the instrument per se. Potential reasons for the misfit of the two subscales may be: (i) upper secondary school students may have a different understanding of the statements from college students, for whom the test was originally designed. (ii) Cultural differences may lead to differing perceptions of the items. (iii) The importance of showing good performances in science classroom (grade motivation) may be understood as the possibility to succeed in science, which refers to self-efficacy and in consequence, the two items actually designed for assessing grade motivation loaded on the same factor as self-efficacy. Nevertheless, this does not explain why other grade motivation items cluster on one factor. (iv) The subscale self-determination is in contrast to the other more behaviour-oriented subscales (e.g. 'I study hard … , I prepare well … '). The other subscales refer more to self-perceptions ('I enjoy learning science … , Learning science will help me get a good job') and may be therefore less related to effort behaviour.

Third, the validity of the SMQ-II is strongly supported by its relations with other variables reported in the literature. Glynn et al., (2011), Goldschmidt and Bogner (2015) or Obrentz (2012) reported correlations with achievement. Glynn et al., (2011) found higher science motivation of science majors than of non-science majors; and Zeyer and Wolf (2010) even reported a correlation between brain types and science motivation. The positive correlations between most of the motivational components are in line with social-cognitive theory (e.g. Ryan & Deci, 2000). Glynn et al., (2011) also reported those correlations.

To summarize, the SMQ-II seems to provide useful information matching with findings in the literature and appears to fulfil the needed quality criteria. However, possible shortcomings of the subscales grade motivation and self-determination need examination.

Differences between college and high school students in science motivation

When comparing results with the analysis of Glynn et al., (2011), similarities in the ranking of the subscale are given. In our sample as well as in the sample of Glynn et al., (2011), the highest mean scores of students were found in the subscale grade motivation. Similar to our subjects, in Glynn et al., non-science majors showed a quite low career motivation, whereas science majors rated career motivation as more important. This relation might partly be due to our age group, since 10th graders still have to complete two more school years before making career decisions. A career in science may not yet be a long-time goal for most 10th grade students whose conceptions of future employment may still appear too vague. The subscale career motivation may be more relevant for college students or high school students who have almost completed their school life – or more irrelevant for those who are not aiming for a science career (see non-science majors in Glynn et al., 2011). To examine differences in career motivation between different school types, age groups or before and after an internship may also be of interest.

The differences between college students and our sample are also evident in the subscales of self-determination and self-efficacy: college students achieved high rates in self-determination compared to upper secondary school students. The opposite is true for the subscale self-efficacy: adolescents score high and college students low. Studies using the SMQ or the SMQ-II as a whole or in part support our findings: Glynn et al., (2011; about 360 science majors and 310 non-science majors, mentioned above) as well as Obrentz (2012; about 400 college students enrolled in an introductory general chemistry lab) describe higher perceived self-determination than self-efficacy of college students. In contrast, Bryan et al., (2011; 288 high school students, between 14 and 16 years old) or Zeyer et al., (2013; students of upper secondary school) show that, on average, secondary school students reported lower self-determination than self-efficacy. One explanation for the different self-determination levels may be that college students had already chosen their field of study and organized their work autonomously. Neither parents nor lecturers force them to learn, do their homework, prepare for tests, or sometimes even to participate in class. Also, the fact that most of the college students have been science students or at least participated in a science course explains the agreement of the results in many studies: most of the test persons choose to study science-related subjects. It is likely that they feel self-determination in their science learning. Secondly, secondary school students are more dependent on authority persons like parents and teachers. The imbalance between control of parents/teachers and the desire for autonomy especially during adolescence can lead to a feeling of heteronomy and to a lower perceived self-determination (e.g. Eccles et al., 1993). The social aspects in school classes compared to college situations have to be taken into account: adolescents work in classes with up to 30 peers, a teacher normally knows all students' names, ensures regular participation, completion of homework or active involvement during lessons. School students are to a degree directed by the teacher or even their peer group and are not totally autonomous in their science learning. Most college students voluntarily join courses, while school students do so compulsorily. The recurring divergence of perceived self-determination between college and school students stresses the difference between the two educational approaches.

Differences between boys and girls in self-efficacy and self-determination

Gender differences were observed only in self-determination (higher for females) and self-efficacy (higher for boys). The subscale self-efficacy measures the belief in individual success (e.g. 'I believe I can master science knowledge and skills', Glynn et al., 2011, item 18). Boys are more confident about their science status than girls are. Social learning theory (Bandura, 1977) is relevant here: when we observe the success of role models similar to ourselves, the belief in our own capability to master a task is fostered. With respect to this assumption, our findings make sense: male role models still seem to be the 'successful gender' in the field of science (e.g. Ceci & Williams, 2007). It is' also worth mentioning that parents' verbal support and acknowledgement in children's academic success can strongly promote self-efficacy beliefs (Ferry, Fouad, & Smith, 2000). Parents often underestimate their daughters' academic competence and consider science as a male domain (Meece & Courtney, 1992).

In accordance with our results, Wiggfield, Eccles, and Pintrich (1996) found that primary school pupils report equal confidence in their abilities regarding mathematics, while in middle school, girls reported a lower self-efficacy than boys. Obrentz (2012) and Glynn et al., (2009) reported female participants also as lower scoring in self-efficacy. Zeyer et al., (2013) found that female students of different nationalities of upper secondary school score lower in self-efficacy. In contrast, Britner and Pajares (2001) described middle school girls as feeling higher in self-efficiency. This, in spite of all the gender related findings, implies that further factors may influence self-efficacy. For example, Pajares (1996) described smaller gender differences in self-efficacy for students of similar competence levels. Exposure to course contents, response biases, measurement practices and gender orientation beliefs may also contribute some influence (Pajares, 2002).

Similar to Glynn et al., (2009, 2011), self-determination was perceived higher by girls than by boys in our study. We can assume that females experience their learning as more self-controlled than boys. The higher self-determination of the girls compensates for their lower self-efficacy and leads to the equality of female and male in overall science motivation. This outcome may result from girls being more diligent and engaged in educational contexts, which manifests itself in behaviours like taking notes, sitting in front of class or doing assignments (Zusman, Knox, & Liebermann, 2005).

The fact that girls' overall science motivation score does not differ from boys' implies that the lack of a feeling of self-efficacy of girls may cause gender-specific effects, like, for example, low interest of women in science, described by Rocard et al., (2007). The support of this motivation by, for example, providing sufficient feedback, encouraging students in setting their own standards or the use of tailored educational programmes that promote mastery experiences (Pajares, 2002) may increase girls' interest in science.

Extrinsic motivation vs. intrinsic motivation

Our sample scored high in grade motivation in line with Glynn et al., (2011) or Campos-Sánchez et al., (2014). Similarly, Vedder-Weiss and Fortus (2012) described students as more motivated by external goals related to outcomes of learning than by internal goals. At the same time, intrinsic motivation scored lower than grade motivation in our study as well as in Glynn et al., (2011). This relationship points to a negative interaction of extrinsic rewards (like grades) with intrinsic motivation (meta-analysis, e.g. Deci et al., 1999). The reproducibility of this may show the importance of grades and external feedback together with lower intrinsic motivation to be an inherent part of our education system. Interest and curiosity in science need fostering, instead of emphasizing success in science on external feedback. On the other hand, one indication for educators, based on these findings, is that even if a task has low potential to be intrinsically motivating, to stress the importance of an external goal can also support motivation (Ryan & Deci, 2000).

Personality as predictor for science motivation components?

We observed only very small correlations between self-determination and consciousness and neuroticism. O'Connor and Paunonen (2007) show in their review that personality traits, especially those of the Big Five factors, are strongly connected to scholastic success. The same is said for relations between grades and scores in the SMQ (Glynn & Koballa, 2006; Glynn et al., 2009, 2011; Obrentz, 2012). Furnham and Chamorro-Premuzic (2004) described personality traits as revealing what a person will do. In the same way, Saucier and Goldberg (1996) put their emphasis on phenotypical aspects of the Big Five traits. We expected personality traits to be connected especially with action-oriented items of the SMQ-II. We consider the self-determination scale as the most action-related subscale of the SMQ-II ('I prepare well … , I study hard … , I use strategies … ’). That may be a reason why we found most of our marginal correlations within this subscale.

When considering the few and very small correlations between the SMQ-II and the BFI-10, we have to keep in mind that most of the studies described in the literature only reported correlations of personality traits with academic achievement (e.g. Furnham & Chamorro-Premuzic, 2004 or O’Connor & Paunonen, 2007). Studies that directly examine the relation between motivation and personality (e.g. Komarraju, Karau, & Schmeck, 2009) also report small correlation scores. One logical conclusion is that interrelations between motivation and personality are small. Still, two other aspects have to be considered: (i) that we found a correlation of the Big Five traits only with the self-determination subscale suggests a deviant conduct of this subscale; (ii) nevertheless, the validity of the Big Five questionnaire BFI-10 (Rammstedt & John, 2007) has been proved, application of a more detailed personality questionnaire, for example , the full BFI-44 (Benet-Martínez & John, 1998; John & Srivastava, 1999; John et al., 1991) in the same context may be fruitful.

Conclusion

(i) The SMQ-II seems to provide useful and consistent information matching findings in the literature. Possible shortcomings of the subscales grade motivation and self-determination should kept in mind. (ii) Secondary school students showed low self-determination scores. In contrast, college students are often portrayed as quite self-determined. Therefore, the perceived self-determination of secondary school students needs attention. (iii) Our study stresses extrinsic motivation of secondary school students and college students as the motivational feature contributing most to overall science motivation. This indicates that intrinsic aspects of motivation should be fostered by showing the inherent value of learning content. (iv) The higher perceived self-determination of girls compensates for their lower self-efficacy beliefs and leads to the equality of females and males in overall science motivation score. That suggests that the lower interest of girls in science is not due to a lack of science motivation per se. Supporting the perceived feeling of self-efficacy may help increase girls’ interest in science. (v) No substantial correlations between science motivation and personality traits were observed. That may indicate that personality and motivation both influence academic achievement but are rather independent variables. To investigate this, further research is needed.

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No potential conflict of interest was reported by the authors.

References

Bandura, A. (1977). *Social learning theory*. Englewood Cliffs, NJ: Prentice Hall.
Bandura, A. (1986). *Social foundations of thought and action: A social cognitive Theory*. Englewood Cliffs, NJ: Prentice Hall.
Bandura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (2001). Self-efficacy beliefs as shapers of children's aspirations and career trajectories. *Child Development*, *72*(1), 187–206.
Benet-Martínez, V., & John, O. P. (1998). Los Cinco Grandes across cultures and ethnic groups: Multitrait-multimethod analyses of the Big Five in Spanish and English. *Journal of Personality and Social Psychology*, *75*(3), 729–750.
Black, A. E., & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination theory perspective. *Science Education*, *84*(6), 740–756.
Britner, S. L., & Pajares, F. (2001). Self-efficacy beliefs, motivation, race, and gender in middle school science. *Journal of Women and Minorities in Science and Engineering*, *7*(4), 15.
Bryan, R. R., Glynn, S. M., & Kittleson, J. M. (2011). Motivation, achievement, and advanced placement intent of high school students learning science. *Science Education*, *95*(6), 1049–1065.
Campos-Sánchez, A., López-Núñez, J., Carriel, V., Martín-Piedra, M., Sola, T., & Alaminos, M. (2014). Motivational component profiles in university students learning histology: A comparative study between genders and different health science curricula. *BMC Medical Education*, *14*(1), 46.
Ceci, S. J., & Williams, W. M. (2007). *Why aren't more women in science?* Washington, DC: American Psychological Association.
Costa, P. T., & McCrae, R. R. (1992). *NEO PI-R: Revised NEO Personality Inventory and NEO Five-Factor Inventory (NEO-FFI)*. Odessa, FL: Psychological Assessment Resources.
Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin*, *125*(6), 627–668.
Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York, NY: Plenum.
Eccles, J. S., Midgley, C., Wigfield, A., Buchanan, C. M., Reuman, D., Flanagan, C., & Mac Iver, D. (1993). Development during adolescence: The impact of stage-environment fit on young adolescents' experiences in schools and in families. *American Psychologist*, *48*(2), 90–101.
Ferketich, S. (1991). Focus on psychometrics. Aspects of item analysis. *Research in Nursing & Health*, *14*(2), 165–168.
Ferry, T. R., Fouad, N. A., & Smith, P. L. (2000). The role of family context in a social cognitive model for career-related choice behavior: A math and science perspective. *Journal of Vocational Behavior*, *57*(3), 348–364.
Field, A. P. (2013). *Discovering statistics using IBM SPSS statistics*. London: Sage.
Furnham, A., & Chamorro-Premuzic, T. (2004). Personality and intelligence as predictors of statistics examination grades. *Personality and Individual Differences*, *37*(5), 943–955.
Glynn, S. M., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science motivation questionnaire II: Validation with science majors and nonscience majors. *Journal of Research in Science Teaching*, *48*(10), 1159–1176.
Glynn, S. M., & Koballa Jr., T. R. (2006). Motivation to learn in college science. In J. J. Mintzes & W. H. Leonard (Hg.), *Handbook of college science teaching* (pp. 25–32). Arlington, VA: NSTA Press.
Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2009). Science motivation questionnaire: Construct validation with nonscience majors. *Journal of Research in Science Teaching*, *46*(2), 127–146.
Goldberg, L. R. (1990). An alternative "description of personality": The Big-Five factor structure. *Journal of Personality and Social Psychology*, *59*(6), 1216–1229.
Goldschmidt, M., & Bogner, F. X. (2015). Learning about genetic engineering in an outreach laboratory: Influence of motivation and gender on students' cognitive achievement. *International Journal of Science Education*, Part B, *5*(1), 1–22.

John, O. P., Donahue, E. M., & Kentle, R. L. (1991). *The Big Five inventory—versions 4a and 54*. Berkeley: University of California, Berkeley, Institute of Personality and Social Research.
John, O. P., & Srivastava, S. (1999). The Big Five trait taxonomy: History, measurement, and theoretical perspectives. *Handbook of Personality: Theory and Research*, *2*, 102–138.
Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement*, *20*(1), 141–151.
Kaiser, H. F. (1970). A second generation little jiffy. *Psychometrika*, *35*(4), 401–415.
Kline, P. (1999). *The handbook of psychological testing*. London, NY: Routledge.
Komarraju, M., Karau, S. J., & Schmeck, R. R. (2009). Role of the Big Five personality traits in predicting college students' academic motivation and achievement. *Learning and Individual Differences*, *19*(1), 47–52.
Lovelace, M., & Brickman, P. (2013). Best practices for measuring students' attitudes toward learning science. *Cell Biology Education*, *12*(4), 606–617.
McCrae, R. R., & Costa Jr., P. T. (1997). Personality trait structure as a human universal. *American Psychologist*, *52*(5), 509–516.
McCrae, R. R., & Costa, P. T. (1985). Updating Norman's "adequacy taxonomy": Intelligence and personality dimensions in natural language and in questionnaires. *Journal of Personality and Social Psychology*, *49*(3), 710–721.
McCrae, R. R., & Costa, P. T. (1987). Validation of the five-factor model of personality across instruments and observers. *Journal of Personality and Social Psychology*, *52*(1), 81–90.
Meece, J. L., & Courtney, D. P. (1992). Gender differences in students' perceptions: Consequences for achievement-related choices. In D. H. Schunk & J. L. Meece (Eds.), *Student perceptions in the classroom* (pp. 209–228). Hillsdale, NJ: Lawrence Erlbaum Associates.
Merenda, P. F. (1997). Methods, plainly speaking: A guide to the proper use of factor analysis in the conduct and reporting of research: Pitfalls to avoid. *Measurement and Evaluation in counseling and Development*, *30*(3), 156–164.
O'Connor, M. C., & Paunonen, S. V. (2007). Big Five personality predictors of post-secondary academic performance. *Personality and Individual Differences*, *43*(5), 971–990.
Obrentz, S. B. (2012). *Predictors of science success: The impact of motivation and learning strategies on college chemistry performance*. Educational Psychology and Special Education Dissertations. Paper 77.
Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, *25*(9), 1049–1079.
Pajares, F. (1996). Self-efficacy beliefs and mathematical problem-solving of gifted students. *Contemporary Educational Psychology*, *21*(4), 325–344.
Pajares, F. (2002). Gender and perceived self-efficacy in self-regulated learning. *Theory into Practice*, *41*(2), 116–125.
Rammstedt, B., & John, O. P. (2007). Measuring personality in one minute or less: A 10-item short version of the Big Five Inventory in English and German. *Journal of Research in Personality*, *41*(1), 203–212.
Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H., & Hemmo, V. (2007). *Science education now. A renewed pedagogy for the future of Europe*. Luxembourg: Office for Official Publications of the European Communities.
Rothstein, M. G., Paunonen, S. V., Rush, J. C., & King, G. A. (1994). Personality and cognitive ability predictors of performance in graduate business school. *Journal of Educational Psychology*, *86*(4), 516–530.
Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology*, *25*(1), 54–67.
Saucier, G., & Goldberg, L. R. (1996). The language of personality: Lexical perspectives on the five-factor model. In J. S. Wiggins (Hg.), *The five-factor model of personality. Theoretical perspectives* (pp. 21–50). New York, NY: Guilford Press.
Schunk, D. H., Pintrich, P. R., & Meece, J. L. (2008). *Motivation in education. Theory, research, and applications*. Upper Saddle River, NJ: Pearson/Merrill Prentice Hall.

Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *The Journal of Educational Research*, *95*(6), 323–332.

Soto, C. J., John, O. P., Gosling, S. D., & Potter, J. (2008). The developmental psychometrics of big five self-reports: Acquiescence, factor structure, coherence, and differentiation from ages 10 to 20. *Journal of Personality and Social Psychology*, *94*(4), 718–737.

Stevens, J. P. (2009). *Applied multivariate statistics for the social sciences*. New York, NY: Routledge.

Tupes, E. C., & Christal, R. E. (1961). *Recurrent personality factors based on trait ratings* (pp. 61–97). San Antonio, TX: USAF ASD. Lackland Air Force Base.

Vedder-Weiss, D., & Fortus, D. (2012). Adolescents' declining motivation to learn science: A follow-up study. *Journal of Research in Science Teaching*, *49*(9), 1057–1095.

Wigfield, A., Eccles, J. S., & Pintrich, P. R. (1996). Development between the ages of eleven and twenty-five. In D. C. Berliner & R. C. Calfee (Hg.), *The handbook of educational psychology* (pp. 148–187). New York, NY: Macmillan.

Zeyer, A. T., Çetin-Dindar, A., Md Zain, A. N., Jurišević, M., Devetak, I., & Odermatt, F. (2013). Systemizing: A cross-cultural constant for motivation to learn science. *Journal of Research in Science Teaching*, *50*(9), 1047–1067.

Zeyer, A., & Wolf, S. (2010). Is there a relationship between brain type, sex and motivation to learn science? *International Journal of Science Education*, *32*(16), 2217–2233.

Zusman, M., Knox, D., & Lieberman, M. (2005). Gender differences in reactions to college course requirements or "Why females are better students". *College Student Journal*, *39*(4), 621–626.

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